A MAP CODIFICATION SYSTEM FOR ANALOGUE SELECTION BY MACHINE METHODS

JAMES L. COX

A MAP CODIFICATION SYSTEM

FOR ANALOGUE SELECTION

BY MACHINE METHODS

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FOR ANALOGUE SELECTION
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by

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Lieutenant Commander, United States Navy

Submitted in partial fulfillment
of the requirements
for the degree of

MASTER OF SCIENCE
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PREFACE

Two of the more important trends in meteorology are: (1) the use of machine methods and (2) the development and use of objective methods for producing weather forecasts. In keeping with these trends, it is the aim of this paper to develop a multi-purpose map codification system, depicting the general flow characteristics, designed primarily for analogue selection and forecasting by machine methods.

This paper was prepared at the U.S. Naval Postgraduate School, Monterey, California, during the period September to December, 1955.

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TABLE OF SYMBOLS AND ABREVIATIONS

"X" Overpunch	Eleventh Punching Position on IBM Card
X/	Eleventh Punching Position on IBM Card
"Y" Overpunch	Twelfth Punching Position on IBM Card
Y/	Twelfth Punching Position on IBM Card
DI	Flow Direction--Flow Intensity Code Group
△	Real High Pressure System
○	Real Low Pressure System
	False High Pressure System
⊕	False Low Pressure System
/	Ridge
	Trough
LIT	Low Location--Intensity--Trough Code Group
HR	High--Ridge Code Group

CHAPTER I

INTRODUCTION

1. General comments.

The statement, "Everybody talks about the weather, but nobody does anything about it", often attributed to Mark Twain, was actually a statement contained in an editorial by Charles Dudley Warner published in the "Courant" in Hartford, Connecticut in 1890. The quotation, though humorous, is not quite true today. Much time, effort and large sums of money have been and are being spent to further our knowledge of the extremely complex physical processes involved in the exchange of energy between the earth, the earth's atmosphere and the solar system. It is this exchange of energy which produces our weather and its changes. Extensive knowledge of the meteorological elements which constitute our weather and their spatial extent, together with a complete understanding of the physical processes involved, would make near perfect weather forecasting possible, a state not expected to be attained. A comprehensive understanding of the above mentioned factors and physical processes is required to satisfactorily answer the question, "What will the weather be?" [10].

Many forecasting techniques have been developed to aid the forecaster in increasing the accuracy of his forecasts. Willett [10] classifies forecasting techniques as belonging principally to one of two major types, those classified as "extrapolation" and those classified as "physical". He defines the two major types and subdivisions as follows:

> 1. <u>Extrapolation Techniques</u>--based on the existing state and trend of the weather, exclusive of modifying physical factors.
>   a. <u>Statistical techniques of extrapolation</u>--based on time sequence of change and association of the weather elements individually in restricted localities.....

b. Synoptic techniques of extrapolation--based essentially on the extrapolation of synoptic weather patterns......

c. Mathematical techniques of extrapolation--based on various manipulations of the equations of motion and continuity....

2. Physical Techniques of Forecasting the Weather--based on a consideration of the physical factors which may actively modify the existing state and trend of the weather as it progresses....

Since the perspective of the forecaster must depend upon the length of the forecast period, there is great diversity in the forecasting methods or techniques that have been developed. There is not only the variety of methods but also variety in the degree of objectivity in each method. In general, forecast methods vary from those based principally on extrapolation-type techniques and used by the short-period forecaster to those based upon physical reasoning and statistical procedures but used by the extended- and long-period forecaster.

As stated earlier, two of the more important current trends in meteorology tend toward the use of objective and machine methods for producing weather forecasts. It is the goal of objective forecasting to eliminate, insofar as possible, that part of the forecasting procedure which depends on the subjective judgments of the forecaster. It is believed that the use of machine methods for producing weather forecasts has been attempted only twice. The first attempt, by the Air Force [7] during World War II, dealt with analogue selection by machine methods. Frequently, many of the analogues selected by the machine from a punch-card file consisting of 40 years of sea-level maps (January 1889 through June 1939) bore little resemblance to the current map. This dissimilitude was due to the fact that too much leeway was allowed in coding the locations and intensities of the pressure systems. This method considered neither the past history of the analogues nor the upper-air flow patterns

associated with them. The second attempt at forecasting by machine methods, which is in the experimental state today, is that of numerical weather prediction. The interest of the theoretical meteorologist in numerical weather prediction was greatly stimulated by the development of electronic computers. The theoretician, quick to realize the potentialities of electronic computers, began concentrating his efforts on formulating the problem of numerical weather prediction for high-speed machine computation. It was not until recently that facilities were available which made it feasible to study and improve upon Richardson's results, published in 1922, of the first attempt at numerical weather prediction. It was Richardson who first realized, about 1910, that the general form of the linearized hydrodynamic equations could be solved by the so-called "finite-difference" method. At present, numerical weather prediction, a result of the theoretical approach to the forecasting problem, is viewed with cautious optimism [6] .

One method of extended forecasting at which several attempts have been made is that of the use of analogues. This method is the one which this writer wishes to pursue, in particular, those based on classification of flow.

The primary argument against the use of analogues is that the weather never follows precisely the same pattern. Wadsworth [9] states that in the light of past experience in forecasting by statistical methods, it is necessary to find a way of classifying the dynamics in order to progress much further and that such a classification might be achieved through the use of analogues. He further states that our failure to date to extrapolate the dynamics properly from known situations is probably due to the

fact that the parameters used to express the synoptic picture are not dynamic in themselves. As a result of this failure, Wadsworth deems it necessary for us to solve more completely the following problems:

a. parameters must be found which adequately classify the static picture of the weather conditions over a large area. They should depict the general features, primarily the flow patterns, over a region even though they may not portray every particular detail. The analogue technique requires a classification in terms of a general flow pattern. Such a classification tends to eliminate the influence of extremely random fluctuations which retard progress in understanding the dynamics.

b. parameters should be found which genuinely classify the dynamic features of large areas. Parameters having real physical significance could possibly be associated with both the static picture and the dynamic processes of the weather elements over an area.

c. the relationship existing between the static and dynamic properties of the parameters should be discernible so that it will be possible to realize what is important from both points of view.

It is desirable that the parameters be hemispheric in scope since the atmospheric state of the entire hemisphere affects the weather patterns at any particular locality. If the general flow characteristics could be determined by studying the dynamics of past situations and extrapolated correctly to obtain the dynamics of the present, then it is quite possible that the network theory of simple linear hypothesis would be adequate to forecast the individual weather at various localities by the use of an operator fitted to a correct dynamic model.

Wadsworth further states that although none of the above problems to his knowledge has yet been solved, there are certain specific conclusions

about analogues in general which appear to indicate that the method holds some hope for future development. Two such conclusions are: (1) when the correlations between the present and past sequence reasonably maintain themselves for at least three days, the analogues are, in general, synoptically and kinematically sound, and (2) there usually exists one analogue (after the fact) which gives a precipitation forecast as good as, if not better than, the 24-hour forecast.

Possibly the first forecasting method based upon the direction of flow of the predominating air currents was the weather-typing system developed by Abercromby [1] in 1885 for use in the North Atlantic. The system consisted of four weather types, Northerly, Southerly, Easterly and Westerly. In 1932, Reed [4] developed the first system of weather types patterned after those of Abercromby for the Northeast Pacific. He found it necessary to add two additional types, Northwesterly and Southwesterly. Both Abercromby's and Reed's weather types were based upon subjective evaluation of the direction of flow of the predominating air currents with relation to the location of the various positions of the so-called centers of action, the major high and low. It is often convenient to refer to the so-called centers of action as though they were the causal factors responsible for the air currents in the wind field about them. However, for practical purposes such as weather forecasting or the analysis of weather types, it is frequently appropriate to recognize them more often as effect rather than cause and to observe in them the indirect but real evidence of the set and strength of the accompanying wind systems. In the words of Sir Napier Shaw [5]

> Instead of looking to the centers of high and low pressure as controlling powers, I should propose to regard them as created by the

distribution of currents which they have been supposed to control... Thus in the free air low pressure and high pressure, depression and anticyclone, are the marginal effects of the flow of an air current in order to adjust the gradient to the current; the particular shape and intensity of the low and high are conditioned by the distribution of currents in the field.

When the high-pressure system is of ordinary or greater than ordinary intensity, the orientation of its major axis (depending upon its location) is important in classifying the behavior of the air currents of the West-wind belt. If the high-pressure system is insignificant, the salient features of the low-pressure systems must be relied on for this purpose. Whether or not it is the axis of the high or in its absence the salient features of the low, the pressure situation which each reveals is interpreted in terms of air flow.

In Vernon's [8] paper on forecasting precipitation for San Francisco, California, he developed an objective method of classifying the flow characteristics by a determination of the zonal and meridional components of air movement based on measurement of pressure gradients. Vernon classified weather maps according to types based upon various combinations of the meridional and zonal components of flow, using the same terminology as Abercromby and Reed.

2. Objective of this research.

The objective of this research is twofold: (1) to develop a multi-purpose map codifications system depicting the general flow characteristics and (2) to show how the codification system can be used for analogue selection and forecasting by machine methods. It is believed that the code system as developed in this paper is readily adaptable for research, both climatological and synoptic. It is intended that the code shall be simple, descriptive, logical and direct reading. Although the selection of

analogues based upon the general flow characteristics and the selection of analogues by machine methods are not original with this paper, it is considered that the combination of the two in the manner as proposed in Chapter III is the first endeavor of its kind.

3. Summary of results.

The first aspect of the twofold objective of this research, that of the development of a multi-purpose map codification system depicting the general flow characteristics, has been accomplished. The code, as was intended, is simple, descriptive, logical and direct reading. It is believed that this codification system which describes not only the instantaneous general flow but also the asymmetry of the pressure systems, over large geographical areas, combined with analogue selection based upon time and space agreement, satisfies two of Wadsworth's requirements, that the parameters must classify the static picture and dynamic features of large areas. It is further believed that the relationship existing between the static and dynamic properties of the parameters is implied by the coded maps. It therefore follows, if the above statements are true, that at least a step in the right direction has been made toward the solution of the three problems as set forth by Wadsworth.

Due to time limitations, the results of actual applications cannot be cited in respect to the second aspect of the twofold objective of this research, that of showing how the codification system can be used for analogue selection and forecasting by machine methods. At best, one can hope only to propose plausible methods of machine solution to such problems as outlined in Chapter III.

CHAPTER II

DEVELOPMENT OF THE CODE

1. Initial considerations.

In order to form a basis for development of a code, the following factors had to be considered initially:

a. subject to be coded;

b. spatial and geographical extent of subject coded;

c. grid or reference system to be used;

d. type of code--letter, number, etc.; and

e. type of equipment to be used.

These initial considerations were resolved as follows:

a. the flow-pattern characteristics as delineated by the analyzed meteorological weather chart are to be coded.

b. the flow pattern for any level in use and over the latitudinal belt 30 to 60 degrees North, the belt of the Westerlies, is to be coded; in addition to the flow-pattern characteristics in this belt, information concerning the high and low pressure systems in the bordering zones, 60 to 70 degrees North and 20 to 30 degrees North latitude, is to be coded.

c. a fixed grid system was chosen as the type of reference system for development of the code; the complexities of a moving reference system make it unacceptable because it violates the principal of simplicity, a requirement of the code.

d. a numerical type code is to be used.

e. the code system was developed for use with International Business Machine Corporation punched-card type equipment, such as the Alphabetic

Collator, Type 89 and the Electronic Statistical Machine, Type 101. The standard IBM punch card used with these machines consists of 80 columns with 12 different punching positions in each column. The lower ten positions of each column are numbered zero to nine. The upper two or OVERPUNCH positions are used for machine instructions and/or to increase the storage capacity of the punch card. Immediately above the "zero" row is the "X" overpunch or 11th punching position above which the "Y" overpunch or 12th punching position is located. It is considered that search techniques and machine programming for analogue selection, objective forecasting, climatological and synoptic research, etc., would be relatively simple using the above type of equipment. The speed of the Alphabetic Collator, depending upon the operation performed, varies from 240 to 480 cards per minute (approximately 14,000 to 28,000 per hour) [2]. The speed of the Electronic Statistical Machine for many operations is 450 cards per minute (27,000 cards per hour) [3]. It is believed that these rates of collation together with the capacity of the punched cards make analogue selection and forecasting feasible by machine methods. The use of more than one machine makes such operations even more practicable. It is quite possible that high-speed electronic computers could be used in conjunction with or in place of the collating type equipment, although the programming of such problems for high-speed computers would be more difficult.

2. Selection of grid size.

The choice of a 30-degree latitude by 30-degree longitude grid size (hereafter referred to as 30-by-30 grid) was for the most part a natural consequence of the use of multiples of 30 degrees as reference longitudes. The 30-by-30 grid is believed to be the optimum grid size for the following reasons:

a. the behavior of the belt of the Westerlies, 30 to 60 degrees North latitude, is an index of the degree of interaction between the air masses of the cold polar region to the North and the warm tropical region to the South.

b. the reference longitudes are well located with respect to reported meteorological information. See Figure 1, page 11.

c. the coded flow characteristics of the belt of the Westerlies on the reference longitudes, when viewed collectively, indicate the general flow pattern as well as contribute some information concerning the pressure systems located within the 30-by-30 grid and border zones.

3. Codification of flow.

In order to describe the flow of the air currents across the reference longitudes between 30 and 60 degrees North latitude, it was decided to use three 10-degree zones, 30 to 40, 40 to 50, 50 to 60. To characterize flow properly, it is necessary to specify both the direction and intensity of the flow. Obviously, if only the direction of flow were used, the same meteorological importance would be attached, generally speaking, to a west wind of 100 knots and one of 15 knots. The intensity of flow is also important in that it lends credence to the reliability of the reported direction of flow. The flow characteristics to be coded for each reference longitude are: (1) the predominant direction and (2) the average intensity of the geostrophic flow across each 10-degree zone. The direction of flow is to be coded to correspond to the nearest point of an eight-point compass. In addition, two special flow indicators, "zero" and "nine" are to be used. The intensity of flow is to be coded to the nearest ten knots. Flow directions and intensities are to be coded in accordance with Table 1, page 12.

FIGURE 1

NORTHERN HEMISPHERE MAP DEPICTING CODING AREAS

TABLE I

CODE VALUES

FOR

FLOW DIRECTION AND INTENSITY

Code Number	Flow Direction (from)	Flow Intensity (knots)*
0	Variable Direction, any intensity	0-5
1	Northeast	6-15
2	East	16-25
3	Southeast	26-35
4	South	36-45
5	Southwest	46-55
6	West	56-65
7	Northwest	66-75
8	North	76-85
9	Curved contours, no predominant direction (Veer or Back), or Shift (Ridge or Trough) and intensity $>$ 5 knots	86-95

* (1) when "X" overpunch used with intensity of flow code number, add 100 knots to coded intensity

(2) when "Y" overpunch used with intensity of flow code number, add 200 knots to coded intensity

The presence of relative maxima in the intensity of flow (hereafter referred to as relative maximum) with a westerly component crossing the reference longitudes north of 30 degrees North latitude can be coded by the use of the "X" and/or "Y" overpunch in conjunction with appropriate direction-of-flow indicators as outlined below.

a. relative maximum information:

(1) to be coded only if intensity of relative maximum $>$ 60 knots;

(2) relative maxima associated with closed contours of pressure systems whose areal extent does not encompass two reference longitudes are not to be coded.

b. "X" overpunch information:

(1) used with only one of the three 10-degree zones of 30-degree latitude belt, 30 to 60 North, for each reference longitude;

(2) indicates presence of relative maximum between 30 to 60 North in 10-degree zone coded.

c. "Y" overpunch information:

(1) used only with 10-degree zone, 50 to 60 North;

(2) indicates presence of relative maximum poleward of 60 degrees North latitude when "X" overpunch also used in either 10-degree zone between 30 and 50 North;

(3) if used alone, indicates presence of relative maximum both poleward of 60 degrees and in 10-degree zone 50 to 60 North.

In order to attain objectivity in coding the direction of flow across the reference longitudes a transparent overlay, Figure 2, page 14, was prepared to assist in coding the flow characteristics of the map. The procedure to be used in coding the direction of flow for each 10-degree

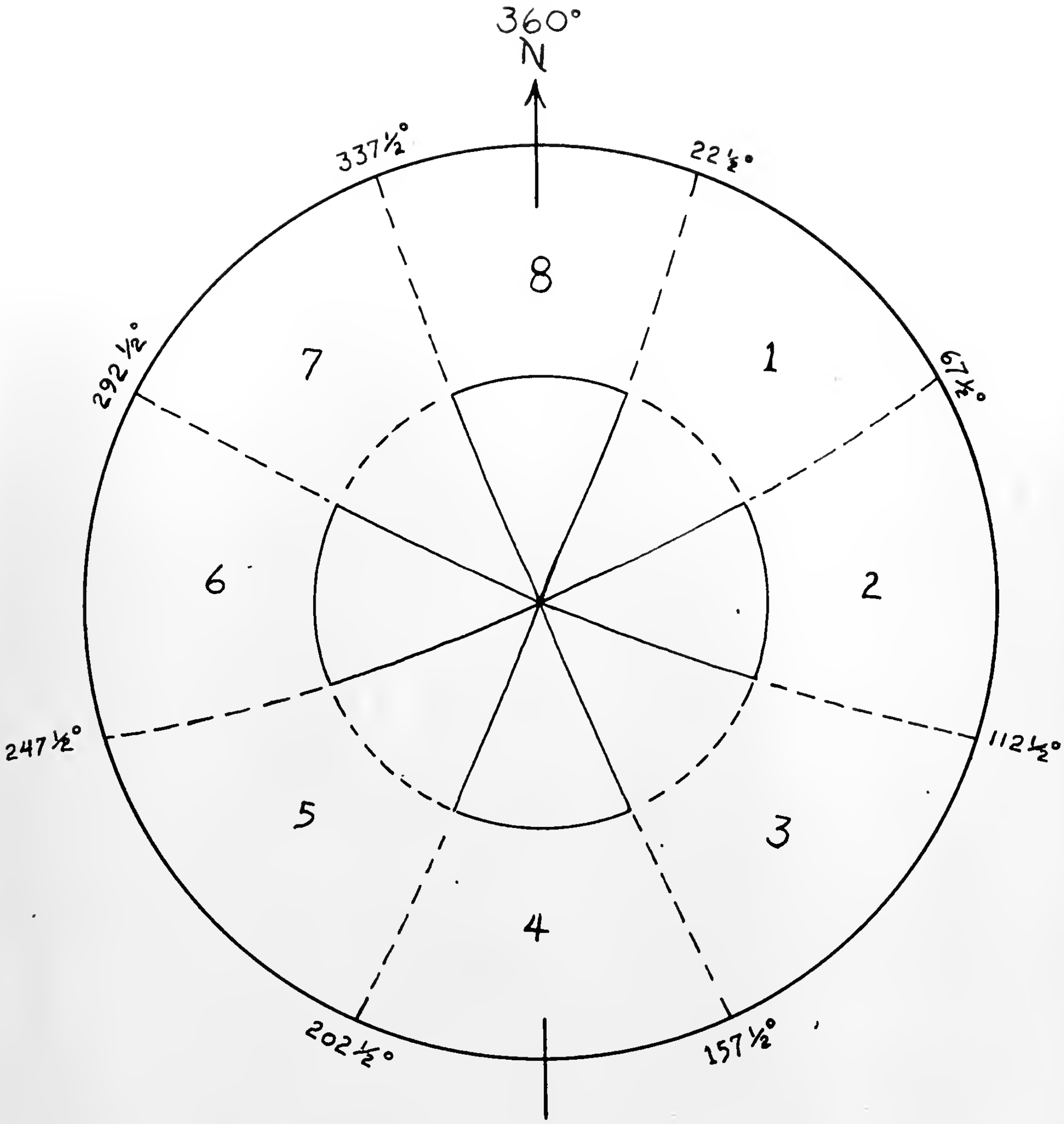


FIGURE 2

FLOW DIRECTION
AND
TROUGH/RIDGE ORIENTATION INDICATOR

Prepared for use with WBAN facsimile map No. 2W 1-55. Reference latitude 45°.

zone is to slide the overlay, properly oriented, down the reference longitude classifying each contour and to code the number which best describes the direction of flow. In coding the flow direction, when possible, the representative direction of the contours upwind from the reference longitude for a distance of 300 miles (the radius of the inner circle, Figure 2, page 14) should be coded. Occasionally when a trough or ridge is near and approaching the reference longitude to be coded, it is convenient to examine the contours downwind a short distance to aid in determining the representative direction. The rule to be followed, when the direction of flow to be coded is on the boundary between two zones, is to code that direction which would represent the flow at a time a few hours later. If the pressure systems have an eastward component, an indication of what the future wind direction will be can often be obtained by examining the wind flow across the longitude five degrees to the west of the reference longitude being coded. The converse would be true of pressure systems with a westerly component.

In coding the intensity of the flow across the 10-degree zones of the reference longitudes, a geostrophic wind scale is to be used. The spacing of the contours, within a distance of 120 miles on each side of the 10-degree zone to be coded, should be examined and the average intensity coded.

For reference purposes an intensity of flow code group, "DI" (flow direction, flow intensity) to be referred to as a DI group, was established.

4. Location of pressure systems.

In order to establish the location of an object it is necessary to use some type of co-ordinate system or to have a reference position from

which a bearing and distance to or from the object can be given. In the location of pressure systems to be coded for purposes of this paper, a modification of the latter type reference system is to be used. Fixed areas located in relation to a central reference position (the intersection of the 45-degree North latitude line and the central longitude of each 30-by-30 grid) are to be used. The 30-by-30 grid and bordering zones were subdivided and identified for pressure-system location as indicated on the transparent overlay, Figure 3, page 18. The overlay is to be properly oriented on the map and the location of pressure systems coded according to the location of their centers. If the center of the pressure system to be coded falls on a boundary line or on the intersection of boundary lines, code the position of the pressure center as if it were located in the zone toward which the arrow on the overlay points. The "Y" overpunch combinations, Y/1, Y/3, Y/5 and Y/7, refer to real pressure systems whereas the Y/2, Y/4, Y/6 and Y/8 combinations refer to false pressure systems located in the sub-areas indicated. The "X" overpunch combinations (not shown on the overlay) are used to indicate the location of false pressure systems in the 30-by-30 grid sub-areas. Real and false pressure systems as used in this paper are defined on page 17.

5. Codification of significant features of pressure systems.

To describe pressure systems properly, it is necessary to include information concerning such significant features as:

a. the intensity of the circulation;

b. their asymmetries; and

c. the more important ridges and troughs associated with their respective centers.

It is to be noted that ridges and troughs do occur which are not directly associated with a particular high or low pressure center. In addition to such features, there are low pressure systems which have undeveloped and/or elongated centers that present difficult code problems. In order to code such features, a false pressure system indicator was devised. Pressure systems as used in this paper are defined as follows:

a. real pressure systems are those systems with closed circulations as indicated by the data and analysis of the chart, to include those centers which can be indicated by drawing intermediate contours; and

b. false pressure systems are those which are associated with (1) non-closed circulations, such as detached troughs and ridges, (2) long troughs and ridges eminating from pressure systems, both real and false, to better indicate length of extensions, and (3) low pressure systems with large undeveloped centers or with elongated centers.

The false pressure system indicators are used to establish reference positions to provide a basis for indicating other information. <u>No</u> closed circulation exists about the point of reference when false indicators are used.

Examples of the use of the false pressure-system indicator are shown on pages 24 through 26, Figures 9 through 12.

Map symbols for the various pressure systems are:

a. real high pressure center, △ ;

b. real low pressure center, ○ ;

c. false high pressure center,  ;

d. false low pressure center, ⊕ ;

e. ridge, ______(solid line); and

f. trough, - - - -(dashed line).

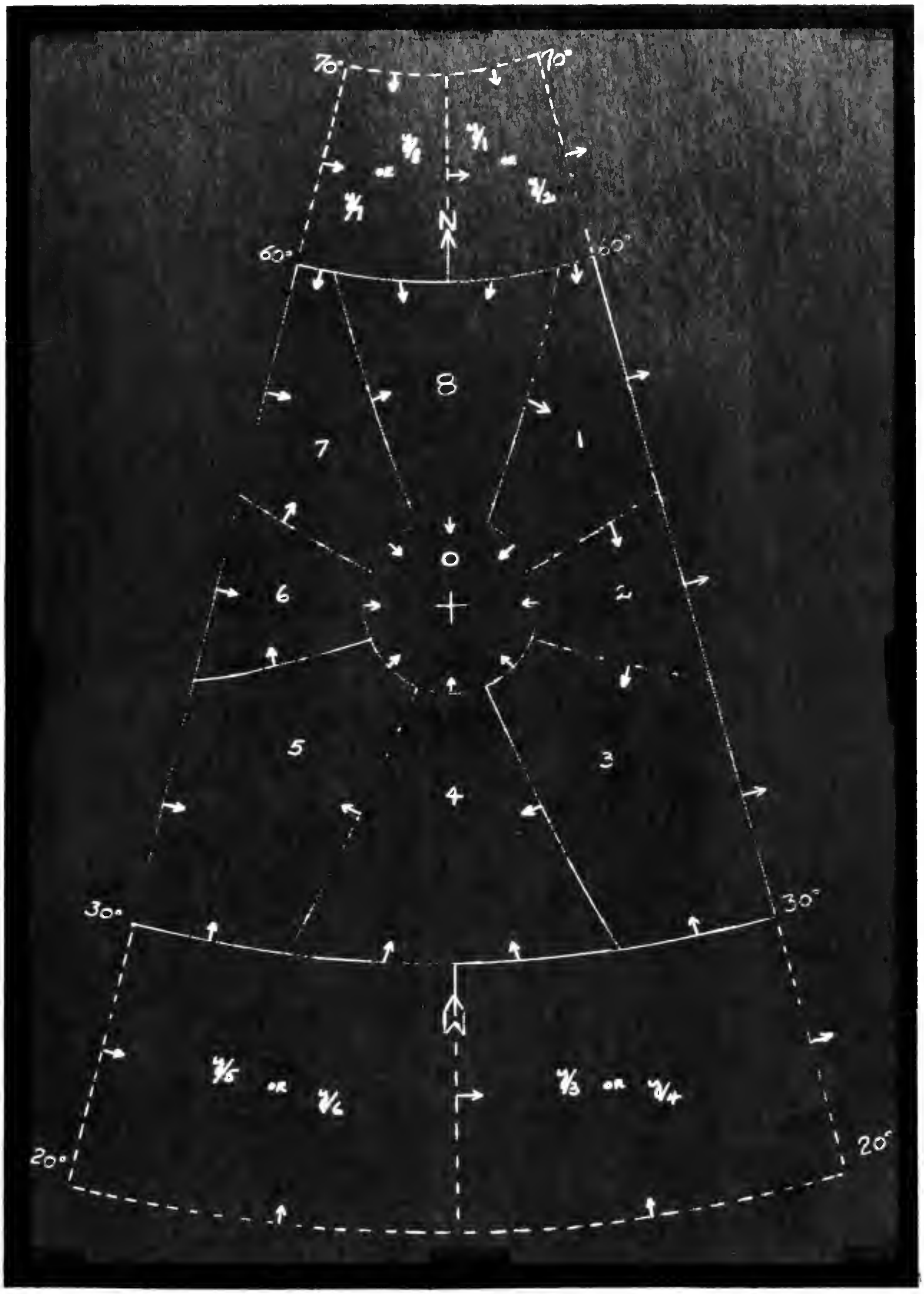


FIGURE 3

PRESSURE SYSTEM LOCATION INDICATOR

To assist in coding the significant features of the pressure systems, two code-group combinations were established, an "LIT" (low location intensity, trough) group and an "HR" (high, ridge) group hereafter referred to as an LIT or HR group. The coded value of the significant feature of a low pressure system, real or false, refers to the particular feature within a radius of 600 miles from the center if the significant feature is of that extent. The same is true for high pressure systems except that a radius of 1200 miles is to be used.

With respect to the LIT group, the intensity column can be used to indicate the following:

a. the average intensity of the flow associated with low circulation when the contours are approximately uniformly spaced. The average intensity is to be coded in accordance with Table 1, page 12, with one exception; the "X" and "Y" overpunch combinations are not to be used to indicate intensities in excess of 95 knots; when intensities stronger than 95 knots are to be coded, use code figure nine;

b. when the "X" overpunch is used in conjunction with a number, one through eight, the code combination means that the semicircle of the low, centered on the direction extending from the low indicated, contains the tightest contour spacing; and

c. when the "Y" overpunch is used with a code number, one through eight, the code combination means that the quadrant of the low, centered on the direction indicated, contains the least tightly spaced contours and that in the remaining three quadrants the contours are approximately uniformily spaced.

The trough column of the LIT group can be used to indicate the following:

a. that a trough extends from the low in the direction indicated;

b. when the "X" overpunch is used in conjunction with a number, one through eight, the code combination means that a trough extends from the low center in two or more directions, the more important of which extends from the low in the direction indicated; and

c. when the "Y" overpunch is used in conjunction with a number, zero through nine, the code combination means that the average intensity of the flow is as coded in that portion of the low containing the tightest contour spacing indicated by the "X" or "Y" overpunch combination in the intensity column.

All of the above variations in code combinations apply to the coding of significant features of false lows with one exception; since no closed circulation exists where the false low indicator is used, the intensity of flow coded in the intensity column refers to the average flow through the trough as measured along the trough line for a distance up to 600 miles.

Coding of the significant feature (ridge) of high pressure systems, both real and false, is similar to that for coding the trough in the LIT group except that the "Y" overpunch combination is not used for the ridge column in the HR group, there being no intensity of flow coded for high pressure systems.

A transparent overlay, Figure 4, page 21, was prepared to assist in coding the asymmetries of low pressure systems. The overlay when properly positioned with respect to the low pressure systems, both real and false, assists by indicating the extent of the asymmetry and its orientation. In coding the orientation of troughs and ridges from their respective centers (including reference positions located by false pressure-system indicators), the overlay, Figure 2, page 14, should be used.

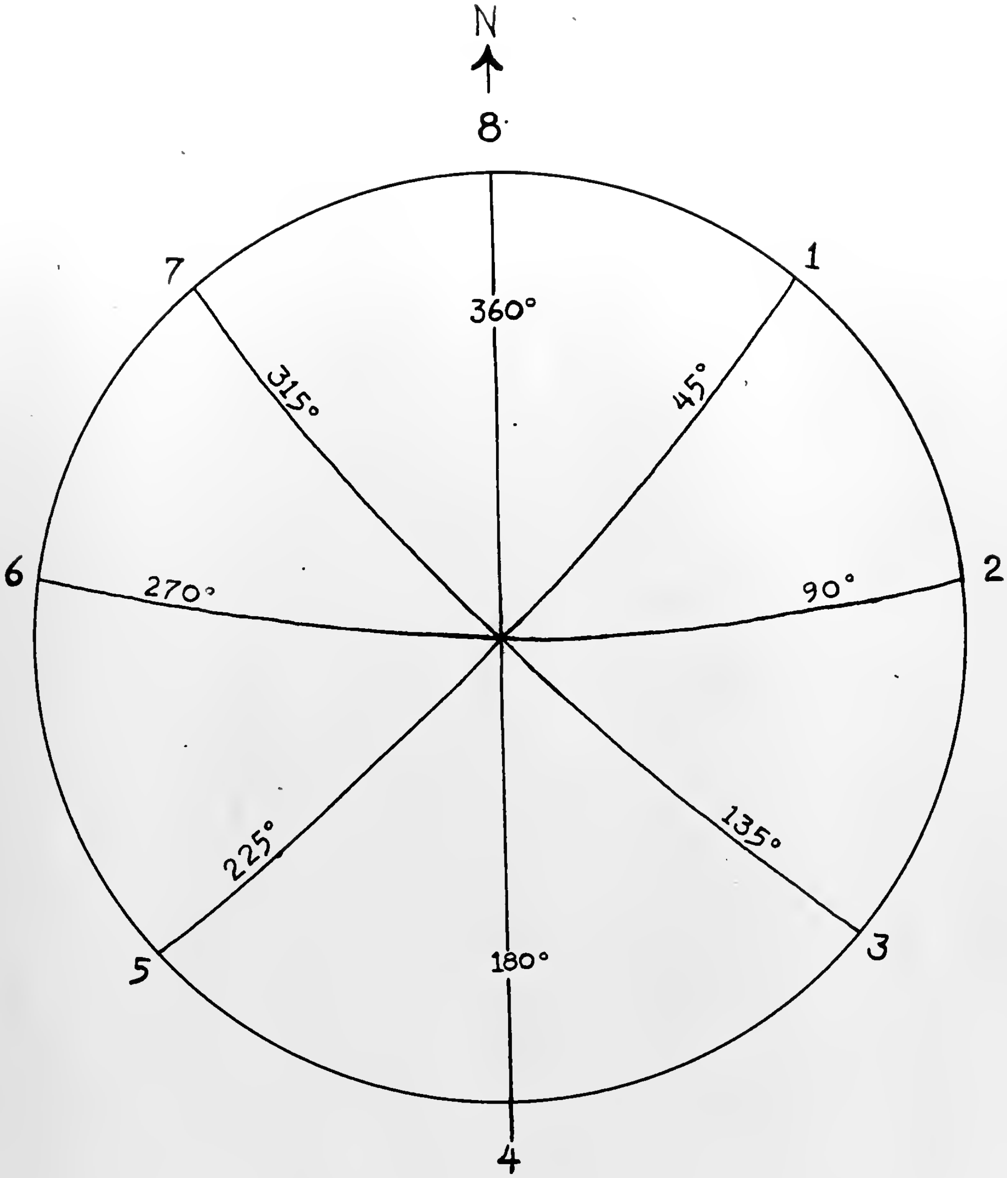


FIGURE 4

LOW PRESSURE SYSTEM ASYMMETRY INDICATOR

Prepared for use with WBAN facsimile map No. 2W 1-55. Reference latitude 45°.

Examples of coding various significant features of pressure systems, taken from 500-mb WBAN facsimile charts during the period from 6 October to 4 November 1955, are shown on pages 23 through 26. A circle or an arc of a circle of 600 or 1200 miles radius from the center of reference is indicated as appropriate.

6. Summary of code.

The code, as developed in this paper, consists of three basic groups:

a. a DI group to depict the flow characteristics across the 10-degree zones of the reference longitudes;

b. an LIT group to depict the significant features of low pressure systems, both real and false, in the area coded; and

c. an HR group to depict the significant features (ridges) of high pressure systems, both real and false, in the area coded.

7. Evaluation of the code.

Thirty 0300Z 500-mb charts, 6 October through 4 November 1955, were coded to test the code's applicability. Also one chart each of the 850-mb, 700-mb, 300-mb and 200-mb levels was coded. Time limitations precluded coding more than a few charts for other than one level. It is considered that the problems encountered in coding the 500-mb level would generally be similar to those of the other levels. No surface chart was coded. It is possible that surface charts can be coded; however, coding would be more difficult due to the effects of topography on the low-level flow patterns.

FIGURE 5

Symmetric low, coded

L I T
7 6

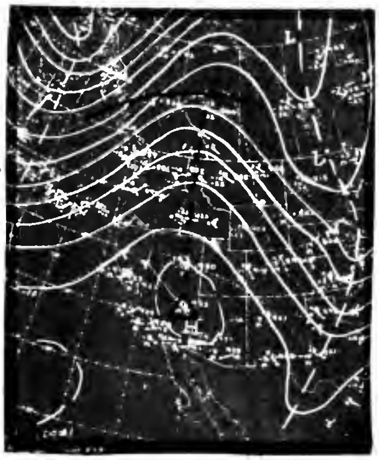
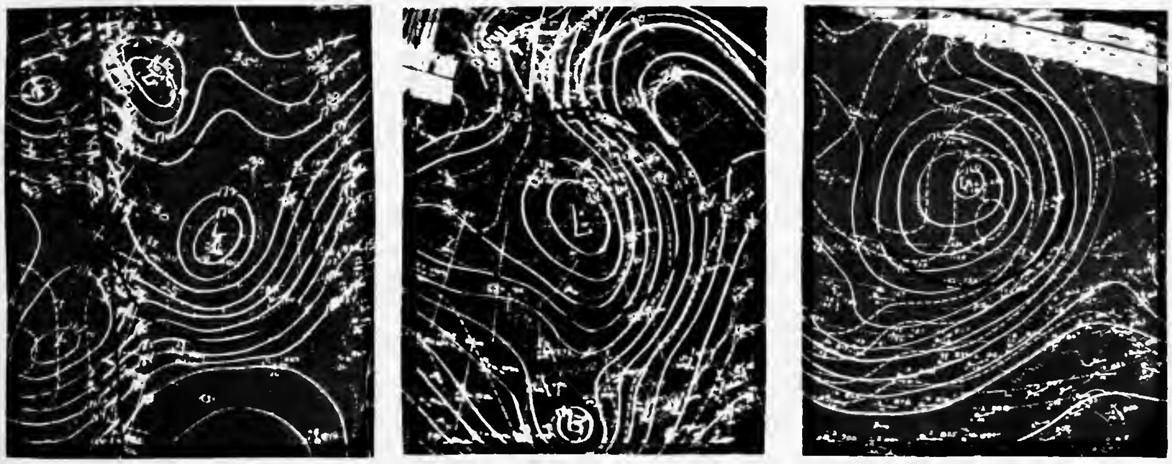


FIGURE 6

Ridge, coded

H R
5 8



a b c

FIGURE 7

Asymmetric lows, illustrating semicircle of tightly spaced contours, coded

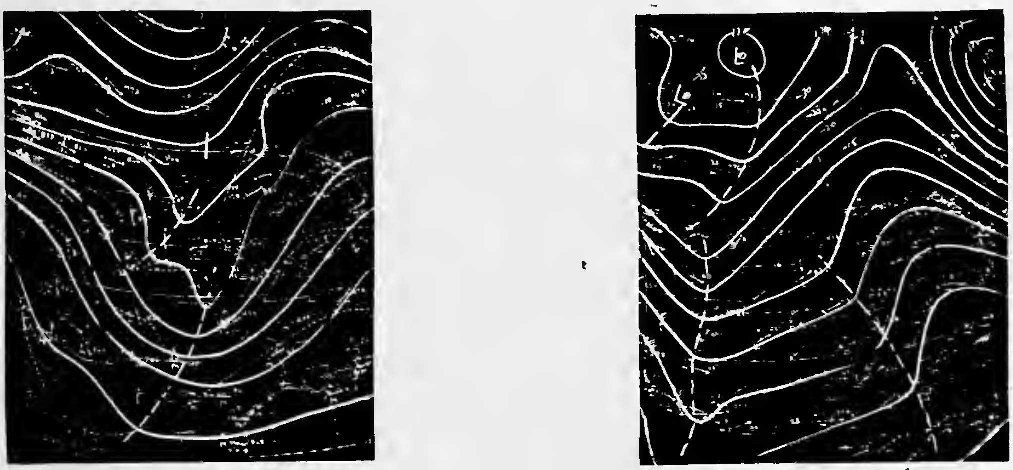
a	b	c
Y X Y	Y X Y	Y X Y
L I T	L I T	L I T
1 3 6	7 2 7	1 2 6

a b

FIGURE 8

Asymmetric lows, illustrating quadrant containing least tightly spaced contours - - contours in remaining quadrants approximately uniformly spaced, coded

a			b		
Y	Y			Y	Y
L	I	T	L	I	T
1	8	5	2	8	7



a b

FIGURE 9

False low indicators, illustrating their use to code detached troughs, coded

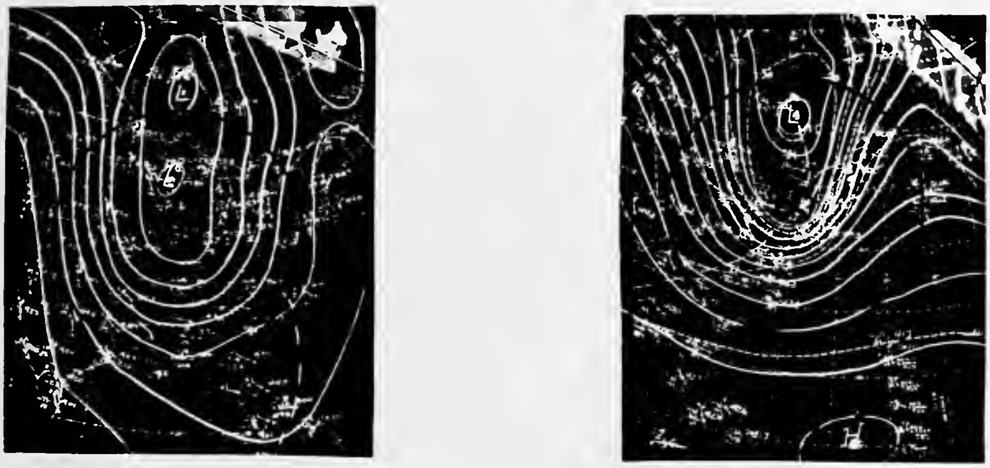
(upper)			(lower)					
X			X			X		
L	I	T	L	I	T	L	I	T
0	3	5	3	5	4	0	3	3

a b

FIGURE 10

False indicators, illustrating their use to better indicate length of troughs and ridges emanating from low and high pressure systems respectively, coded

X X	X X
L I T	H R
7 3 4	2 8



a b

FIGURE 11

False low indicators, illustrating their use to better indicate significant features associated with elongated low centers, coded

X Y Y	X Y Y
L I T	L I T
6 8 6	0 8 8

Figure 12

False high indicator, illustrating its use to code detached ridge, coded

X
H R
8 8

Some difficulties encountered in applying the code were:

a. whether or not to use the flow direction-indicator number nine or to code a predominant direction of flow whenever a trough or ridge line extends across the 10-degree zone to be coded;

b. occasionally in coding the direction of flow across a 10-degree zone, border-line conditions were considered to exist;

c. elongated low pressure systems open on opposite sides of the low center, Figure 11a and 11b, page 25, which resembles an "H" in structure were occasionally encountered; and

d. on the 300-mb and 200-mb charts, a relative maximum either originated or just dipped south of 30-degrees North.

The difficulties were resolved as follows:

a. when trough and ridge lines extend across the 10-degree zones it is considered better in most cases to use the direction-of-flow indicator,

number nine, to characterize the flow rather than attempting to code a predominant direction; such coding in conjunction with the coding of other features of the flow pattern adequately depicts the flow characteristics indicated by the analyzed chart;

b. when the direction of flow to be coded is on the boundary between two zones, code that direction which is expected to represent the flow across the 10-degree zone a few hours later;

c. a false low indicator, when used as illustrated in Figures 11a and 11b, page 25, in conjunction with information about the real low center (as trough orientation or semicircle containing tightly spaced contours, when possible), permits the significant features associated with elongated low pressure systems to be more accurately described; and

d. a provision was not made in the code to indicate the presence of a relative maximum below 30 degrees North because it was not possible to do so without violating a requirement of the code, simplicity.

To evaluate the degree of objectivity in application of the codification system, 12 of the 30 maps coded for the 500-mb level were recoded approximately three weeks after and without reference to the original codification. It was desired to note particularly the degree of objectivity in coding the direction of flow across the 10-degree zones and in the location of real pressure centers. The degree of objectivity in coding these features was high. The exceptions occurred in the codification of flow directions which were considered to be border-line conditions and in the use of the code number nine for codification of flow direction instead of a code number representing a predominant direction. Flow codification differed approximately 15 times out of 252 possibilities, there being 21 flow classifications for each of the 12 recoded maps. Where

coding was different, four were boundary line cases and the remaining were code-nine type cases. The latter was probably due to the fact that as coding progressed the number-nine flow indicator was more extensively used.

As was expected, less objectivity was involved in coding such characteristics as the significant features of pressure systems, the use of the false pressure system indicators, and the intensity of the flow across the 10-degree zones. In the majority of the three cases the codification was the same. Some exceptions were:

a. the semicircle containing the tightest contour spacing was indicated as code combination X/3 instead of X/4 when border-line conditions existed;

b. the intensity of the flow in the semicircle or three quadrants (Y/number combination) containing tightest contour spacing was indicated instead of a trough associated with the low pressure system;

c. in the use of the false pressure-system indicators, more subjectivity was involved in use of the false pressure-system indicators to locate ridges than troughs; the subjectivity was not in the fact that the location of the ridge was not adequately indicated but that the false high indicator was occasionally used in a different locator zone than previously used; and

d. in coding the intensity of flow across the 10-degree zones it was not expected that the coded number for the strength of flow to differ by more than one code number as was the case with one or two exceptions in which the intensity of flow coded differed by two code numbers. The exceptions occurred when a trough crossed a code zone where the contours were

very tightly spaced on one side and not on the other. In coding intensities below code number two, the strength of flow was estimated.

The degree of objectivity indicated above is considered quite satisfactory for the proposed uses of the code system in Chapter III.

8. Example of coded map.

An example of a 500-mb map coded using the code developed in this paper is shown in Figure 13. It should be noted that it is not necessary to code all columns of the LIT and HR groups when significant features are lacking.

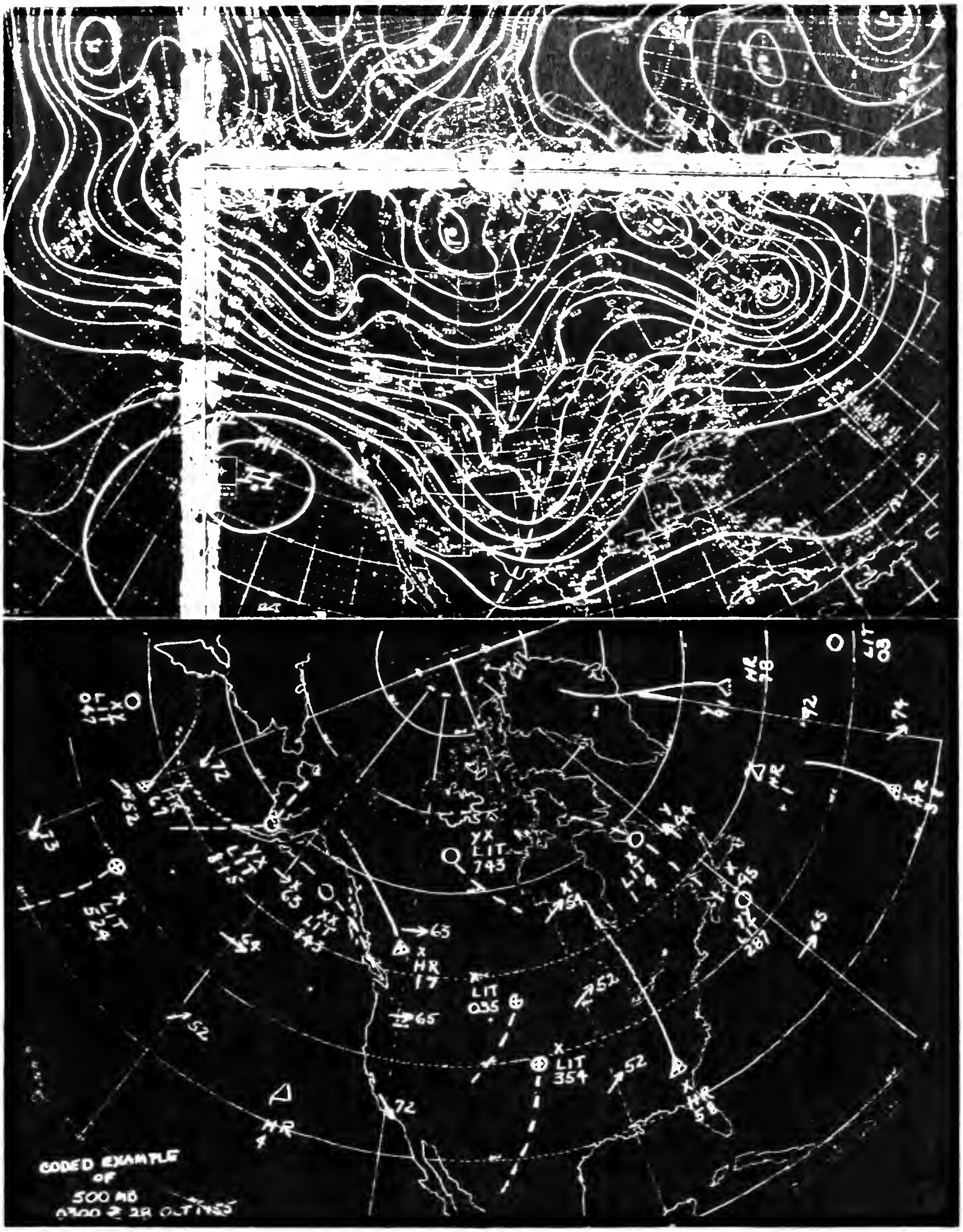


FIGURE 13

EXAMPLE OF CODED 500-MB MAP,
0300Z 28 OCTOBER 1955, USING CODE DEVELOPED IN THIS PAPER

CHAPTER III

PROPOSED USES OF CODE

1. Analogue selection.

The primary purpose for developing the map codification system in this paper is that of analogue selection and forecasting by machine methods. Realizing that there is no such thing as a perfect analogue, it is considered that the best analogue that can be hoped for at this time would be a hemispheric analogue satisfying the general flow characteristics in time and space for a period of three days. It is also realized that to obtain such an analogue requires a large number of multivalued parameters. From the statistical standpoint analogue selection under such conditions is practically impossible. However, the various values of the parameters are not all equally likely; for example, in the belt of the Westerlies, the probability of the flow parameters having easterly components is considerably smaller than for those with westerly components. When the occurrences of different events are not equally likely, the relative frequencies of occurrence must be considered and weighting factors applied in order to determine the probability of obtaining an analogue. If proper weighting factors for the parameters which characterize the general flow pattern were determined for each month of the year the statistical probability of obtaining an analogue would be greatly enhanced.

It is assumed for the purpose of discussion that the flow characteristics for three selected levels in the atmosphere represent the significant features of the atmosphere at any specified time. Three levels which may

be considered to represent the state of the atmosphere are the 850-mb level for the lower troposphere, the 500-mb level for the upper troposphere and the 200-mb level for the lower stratosphere. If a hemispheric analogue satisfying the general flow characteristics for these levels for a period of three days (using 24-hourly maps) could be selected, it seems logical to assume that the sequence of weather events following the analogue selected for a period up to three to five days would repeat itself with a high degree of accuracy. It is upon the premise that such an analogue exists that the proposed procedures for analogue selection and forecasting are based. The three-level three-day analogue is referred to hereafter as a 3-by-3 analogue. It is understood that in attempting to select a 3-by-3 hemispheric analogue, that at any step in the search procedure, the process may fail due to the fact that no analogue exists in the records available. The trend of selecting analogues should be to attempt always a 3-by-3 hemispheric analogue, failing this a 3-by-3 semi-hemispheric analogue, failing this a 3-by-3 octant analogue, etc., if a 3-by-3 analogue for a smaller area is desired. If a 3-by-3 analogue does not exist, the selection of a two-level three-day analogue, etc., could be attempted.

In the choice of parameters for use in analogue selection, only those parameters, direction-of-flow indicators associated with the strongest intensities of flow (never less than 20 knots) and positions of the more important real pressure systems, should be used as major parameters. In the initial search for an analogue satisfying the general flow characteristics, only major parameters should be used. If a major parameter is considered to be a border-line case, it should not be used as such but as an intermediate parameter to simplify collation. The cards

containing possible analogues obtained on the initial search would be further collated using first one and then the other possible coded value of the border-line parameters. Such a technique requires that the large group of cards be collated only once. If several cards are obtained which satisfy the general flow characteristics, collation should be continued using intermediate parameters in order to obtain the best analogue. In the search for an analogue, 12-hourly maps are to be collated but only for those months of the year which might reasonably be expected to contain an analogue, in order to form a basis to start the 3-by-3 analogue selection.

The coded general flow pattern characteristics should be stowed on the IBM punch card as follows:

COLUMN NUMBER	DEFINITION	OVERPUNCH COMBINATIONS	
1 2	Level coded in 100's and 10's of mbs	X 00	Surface chart
		00	1000 mb chart
3	Octant(s)	X/1 X/2	Octants 0 and 1 coded, Octants 1 and 2 coded, etc.
4 5	Hour GCT		
6 7	Day		
8	Month	X/	add 10
9 10	Year (last two digits)		
11	Longitude in 10's of degrees	X/	add 100 degrees
12 13 14	50 to 60N } Flow dir. 40 to 50N } across long. 30 to 40N } indicated column 11	X and Y as defined on page 13	
15-17	Location of low pressure systems, real and false	X and Y as defined on page 16	

(continued)

COLUMN NUMBER	DEFINITION	OVERPUNCH COMBINATIONS
18 19	Location of high pressure systems, real and false	X and Y as defined on page 16
20	Longitude	
etc.		

Figure 14 shows card arrangement of parameters for semi-hemispheric analogue selection based upon general flow characteristics and an example of a card containing coded 500-mb map information for 0300Z 28 October 1955, Figure 13, page 30. Figure 15 shows card arrangement of more detailed information regarding the flow characteristics on an octant basis and an example of a punched card containing such information from the same map as used in Figure 14.

The stowage capacity of the standard IBM punch card restricts the selection of an analogue based upon the general flow characteristics to a semi-hemispheric one-level basis when collation-type equipment is used. At first, one might think that the integrating procedure necessary to select a 3-by-3 hemispheric analogue would be difficult. However, it is believed that in accordance with the collating procedure outlined below, the fitting together of the parts to obtain the whole is relatively simple.

The collating procedure is as follows:

1) select analogue for one level for each semi-hemisphere;

2) select hemispheric analogue for level in question from cards obtained in step 1) by comparing the date-time groups to ascertain if any two are of the same date and time; if a hemispheric analogue exists it must come from the analogues for the two semi-hemsipheres selected;

3) repeat steps 1) and 2) for each of the two remaining levels;

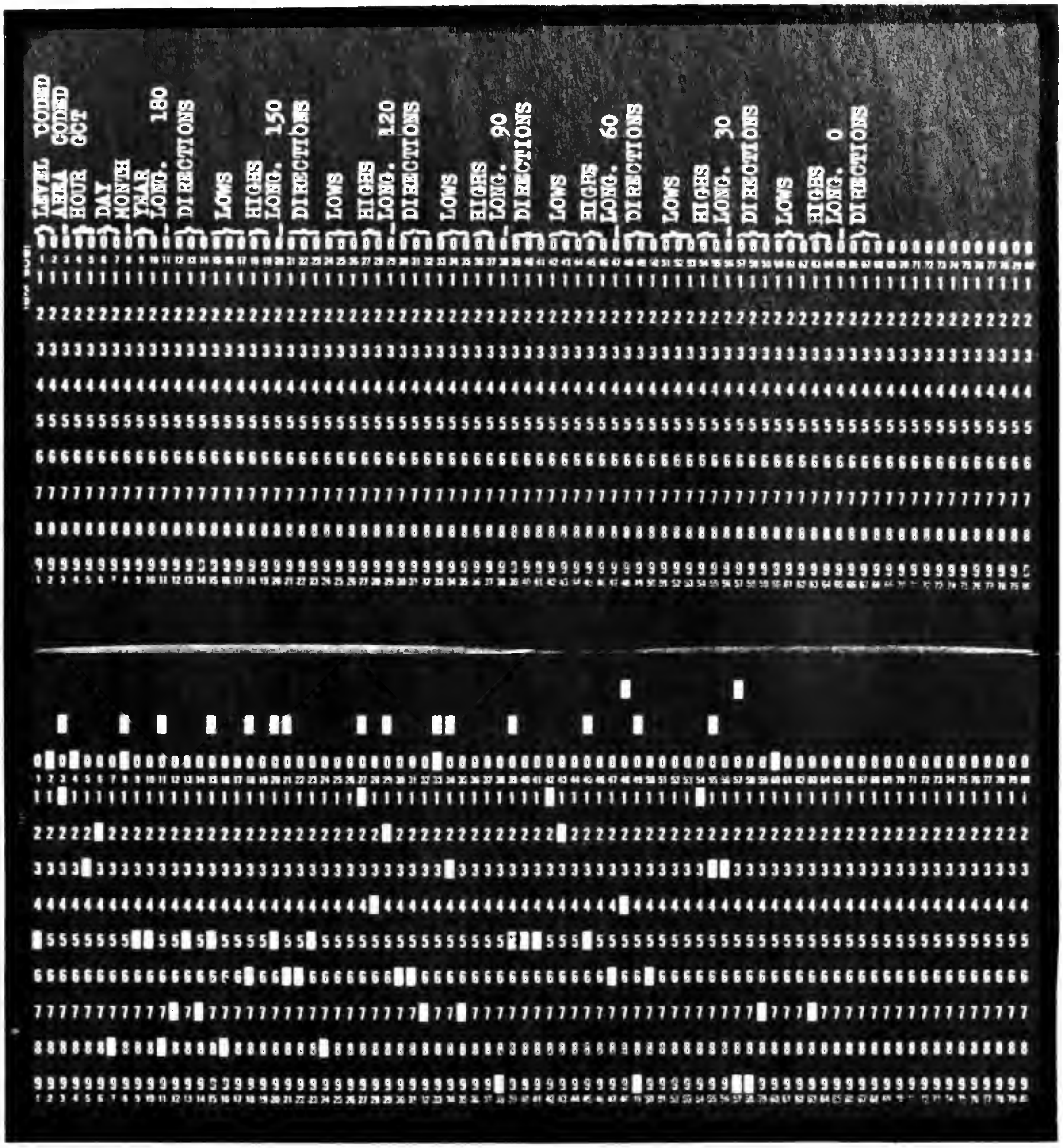


FIGURE 14

IBM PUNCH-CARD ARRANGEMENT OF PARAMETERS
FOR SEMI-HEMISPHERIC ANALOGUE SELECTION
BASED UPON GENERAL FLOW CHARACTERISTICS
WITH CODED 500-MB EXAMPLE, 0300Z 28 OCTOBER 1955

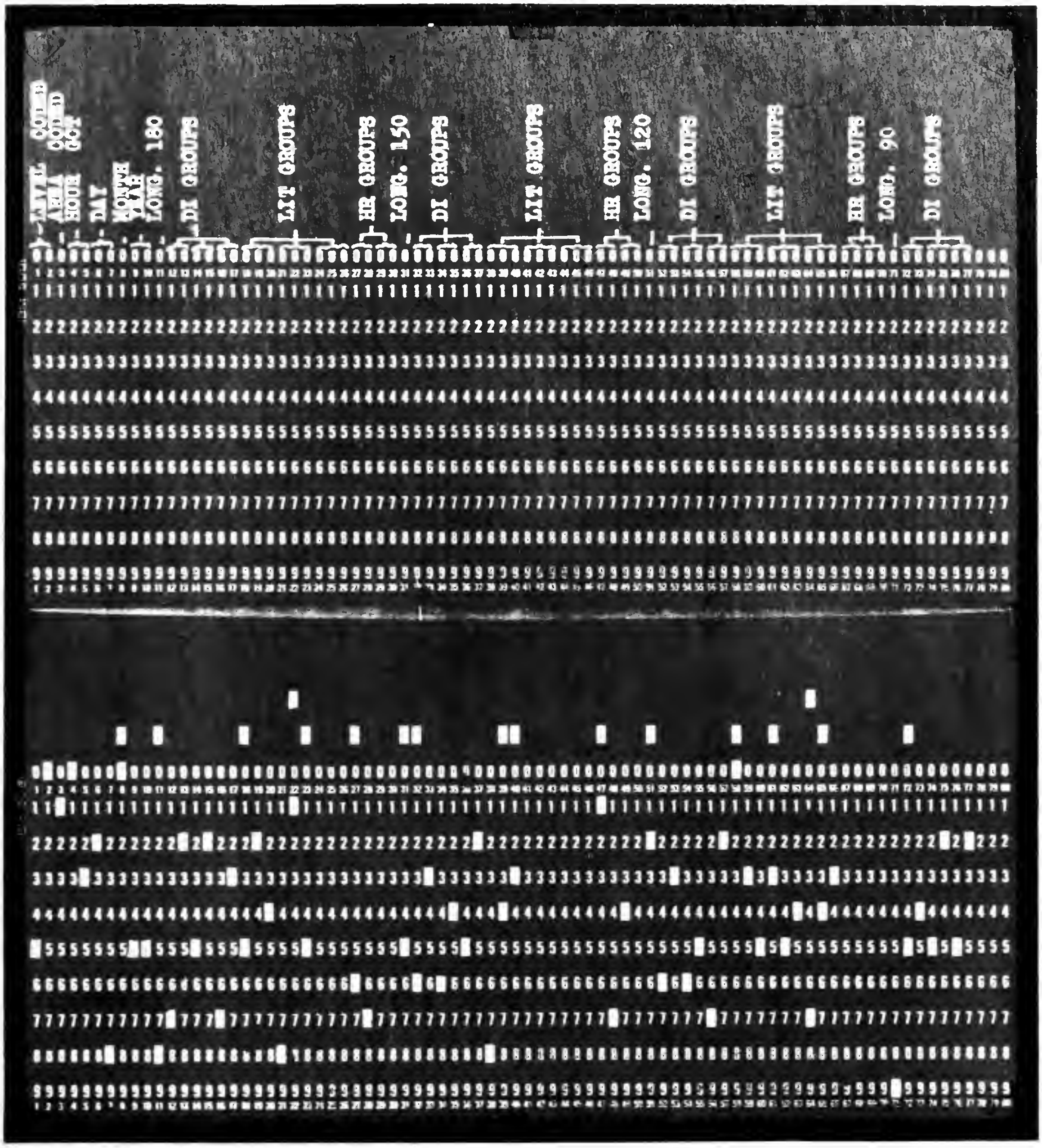


FIGURE 15

IBM PUNCH-CARD ARRANGEMENT OF PARAMETERS
OF MORE DETAILED REPRESENTATION OF FLOW CHARACTERISTICS
ON AN OCTANT BASIS WITH CODED 500-MB EXAMPLE,
0300Z 28 OCTOBER 1955

4) compare date-time groups of analogues selected for the three levels to ascertain if any three-level combinations are of the same date and time; if so, a hemispheric analogue representing the significant state of the atmosphere at a specific time has been selected; and

5) compare the two previous days' charts of the analogue selected with the two previous days of the current sequence for which the 3-by-3 hemispheric analogue is desired.

The comparison in step 5) can be done quickly by hand collation, that is, by superimposing one card upon the other over a light table to ascertain if the two cards match in the desired columns. If the general flow patterns for the three days of the probable analogue are the same as those of the current sequence, a 3-by-3 hemispheric analogue satisfying the general flow characteristics has been obtained. The 3-by-3 hemispheric analogue or analogues selected satisfying the general flow characteristics should be examined further in order to determine the best-fit analogue by comparing their respective octants either by inspection of the IBM punched cards containing the detailed octant information or by visual inspection of the actual charts.

2. Objective forecasting.

If a perfect analogue exists and can be identified as such, the forecasting problem would be solved, for it would only be necessary to read the weather directly from the subsequent series of maps of the analogue selected. However, since this is not the case, only a best-fit analogue can be expected satisfying the general flow characteristics. It would therefore seem desirable to know something about the probability of recurrence of the weather associated with the subsequent sequence of maps of

the best-fit analogue selected. In order to accomplish this, it is necessary to store climatological information together with the upper-level flow-pattern characteristics which produced it on IBM punch cards.

One method of obtaining an objective precipitation forecast for an area based upon the general flow characteristics of the analogue selected is as follows:

1) twice daily at 0630Z and 1830Z summarize the weather information for the previous 12 hours by 6-hourly periods for each 10-by-10 degree area centered on longitudes which are multiples of ten;

2) store the summarized weather information for the 12-hourly periods 1830Z to 0630Z and 0630Z to 1830Z with the flow-pattern characteristics of the 850-mb and 500-mb levels for the 0300Z and 1500Z upper-air charts, respectively for each 30-by-30 degree grid and border zones on IBM punch cards as shown in Figure 16 (in order to prevent duplication of stowage of climatological data for the 10-by-10 degree areas associated with the reference longitudes of the 30-by-30 grids, it is necessary to offset the 30-by-30 degree area for which the climatic information is to be stored five degrees to the East of the 30-by-30 grid for which the general flow pattern characteristics are coded);

3) prepare a search card containing the general flow characteristics for each 30-by-30 grid and border zones of the subsequent 12-hourly maps of the analogue selected; it is assumed that if the general flow characteristics of the current map sequence are satisfied by the general flow characteristics of the best fit 3-by-3 analogue, that the same is true of the general flow characteristics of the intermediate maps of the respective sequences;

FIGURE 16

IBM PUNCH-CARD ARRANGEMENT OF PARAMETERS FOR OBJECTIVE PRECIPITATION FORECASTING

4) collate the historical card file prepared in accordance with steps 1) and 2) using the search cards for each 30-by-30 grid prepared in step 3) containing the general flow characteristics of the subsequent 12, 24, 36, 48, etc., hourly maps of the analogue selected; and finally

5) collate the cards obtained in step 4) satisfying the general flow characteristics at the specified times for each 30-by-30 grid to separate the cards belonging to each 10-by-10 area, from which the probability of occurrence of the types and amount of precipitation for each area can be determined.

Similarly, if the climatological information for a single station were stored on IBM cards together with the upper-level general flow characteristics which produced it, an objective precipitation forecast could be obtained by collating the historical card file using a search card as prepared in step 3) above.

In the foregoing suggested methods of objective precipitation forecasting, the general flow characteristics used in preparing the search cards were based upon the subsequent sequence of maps of the analogue selected. This does not necessarily have to be the case, for if by "knowing" the general flow characteristics of the atmosphere at some future time, whether obtained from analogues, by numerical weather prediction or from prognostic charts made by other means, the same procedures can be carried out.

Another method of objective forecasting based upon storing general flow characteristics together with climatological information on IBM cards, is that of time lag correlation. If the climatological information for the 10-by-10 degree areas for the period 24-48 hours subsequent to each of the

0300Z and 1500Z upper-air maps were stored with the general flow characteristics of the respective maps on IBM cards, an objective forecast could be obtained by collating the historical card file using a search card based upon the general flow characteristics of each 30-by-30 grid and border zones of the latest upper-air charts. The goal of such a procedure as this is the same as that of Vernon's objective method for forecasting precipitation 24-48 hours in advance for San Francisco, California, except that the forecast is an area forecast rather than a single-station one. Application of this procedure requires considerably more effort than that of Vernon's, since the flow characteristics at more than one level are being considered.

3. Research.

The codification system as developed in this paper is readily adaptable for research, both climatological and synoptic. The code system in conjunction with IBM punch-card stowage of weather information provides a method for multidimensional representation of climatological data; that is, the spatial and geographical extent of the general flow pattern characteristics (the cause) together with the climatological data (the effect) which it produces. One example of such stowage was illustrated in the preceding section on objective forecasting, Figure 16. However, for climatological purposes it is considered more desirable to code the direction and intensity of flow across each 10-degree zone between 20 and 70 degrees North for all longitudes which are multiples of ten. Stowage of such flow-pattern information for each level on IBM punch cards on a 60-degree sector basis provides a rapid means of compiling wind-rose information on a hemispheric scale. This type of information compiled monthly, especially

over oceanic areas, would be quite important in planning routes for commercial airline operations as well as for various types of operational planning for military uses. Punched-card stowage of summarized 12-hourly weather information regarding precipitation for each 10-by-10 degree area in conjunction with the flow characteristics across the 10-degree zones of all longitudes (multiples of 10 degrees) permits rapid preparation of precipitation studies, containing wind rose information as well as the frequency of occurrence and rate of precipitation, which would be very important in problems involving rates of precipitation and precipitation run off, for example, flood control and reservoir construction problems.

The stowage of the general and more detailed flow pattern characteristics on IBM cards as shown in Figures 14 and 15 on pages 35 and 36, respectively, permits rapid determination of the frequency of occurrence of certain synoptic features, such as highs, lows, various types of blocking situations, etc. for any desired area. This can be accomplished simply by indicating on a chart the positions of the centers of the highs and/or lows which comprise the desired synoptic feature and by collating the historical card file using a search card containing the coded locations of the pressure centers concerned.

4. Map analysis code.

The codification system can also be used as a map analysis code. The only modification to the code required is the substitution of a coordinate-type location system in lieu of the area type for the location of pressure centers as used in analogue selection and forecasting. Other modifications, such as the choice of designators to identify real and false pressure systems, are required to make the code more usable as an analysis code. The latter modifications could be patterned after the

present International Analysis Code (IAC). The principal advantages of this code over the IAC code are (1) that the general flow pattern characteristics can be depicted in a much more compact form and (2) that from the coded asymmetries of low pressure systems an estimation of their probable future movement can be made. In regard to the first advantage, the general flow-pattern characteristics for a 60-degree sector of a hemisphere could be completely coded using approximately 60 five-digit code groups instead of requiring between 120 and 150 groups as does the use of the IAC code in its pointwise location of significant contours.

An example of the accuracy with which an upper-air chart can be reproduced from coded information is shown in Figure 17. The map was reconstructed some three weeks after it was coded without the aid of previous maps as history and also without reference to the original map. The reproduced map compares favorably with the actual map in all important details. A few minor differences to be noted on the reproduced map are (1) the ridges are in some cases more sharply peaked, (2) the intensity of flow across the ridge over the eastern United States is too strong, and (3) the minor inflections in the contours do not appear on the reconstructed map.

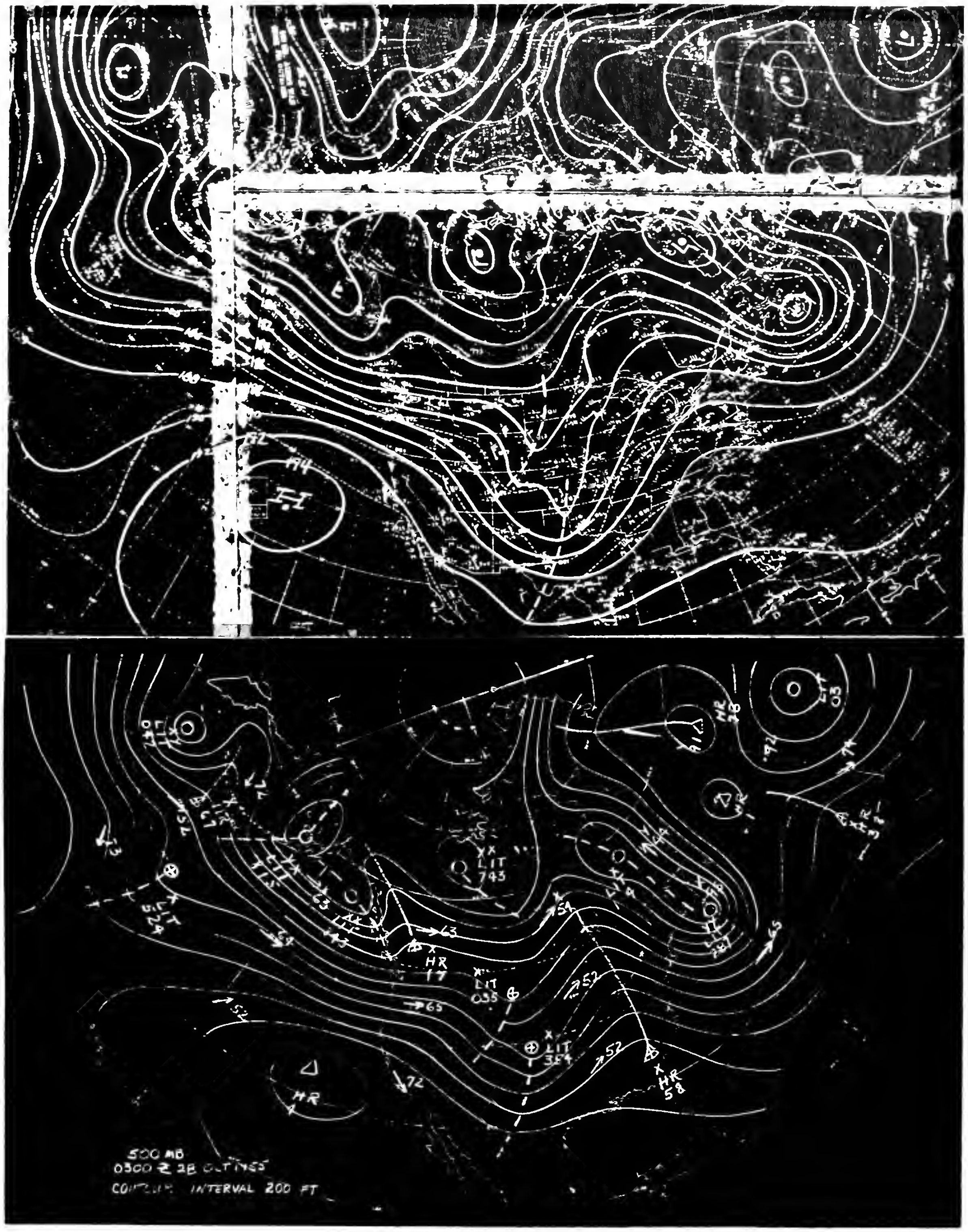


FIGURE 17

EXAMPLE OF 500-MB MAP,
0300Z 28 OCTOBER 1955, RECONSTRUCTED FROM CODED INFORMATION

CHAPTER IV

CONCLUSIONS

1. Conclusions.

The first aspect of the twofold objective of this research, that of the development of a multi-purpose map codification system depicting the general flow characteristics, was accomplished. The code, as developed, is simple, descriptive, logical and direct reading.

Due to time limitations, the results of actual applications could not be cited in respect to the second aspect of the twofold objective, that of showing how the codification system can be used for analogue selection and forecasting by machine methods. However, reasonable procedures for machine solutions of the problems of analogue selection and forecasting have been outlined in their respective sections of Chapter III. In addition to the above uses, the code system in conjunction with IBM punch-card stowage of weather information provides a method for multidimensional representation of climatological data for use in research, both climatological and synoptic; some examples of the types of research are (1) compilation of wind-rose information, (2) preparation of precipitation studies, and (3) determination of the frequency of occurrence of certain synoptic features, such as highs, lows, various types of blocking situations, etc. Finally, the code system can be modified for use as an analysis code that requires considerably less code groups to depict the general flow-pattern characteristics and that enables the forecaster to estimate the probable future movements of the low pressure systems from their coded asymmetries.

2. Suggestions for further research.

It is realized that to institute such a system for analogue selection and forecasting and such a system for multidimensional representation of meteorological data for research purposes, both climatological and synoptic, would require a considerable amount of effort and co-operation of the various weather organizations of this country and of other countries if desired. If established as a joint operation by several countries, the results would be made available to participating nations. Two central collection, analysis and forecast centers, one in Washington, D.C. for the western semi-hemisphere and the other either in Tokyo, Japan or London, England for the eastern semi-hemisphere, would be required to collect, digest and disseminate the appropriate information. The above statements were made in order to indicate the universal extent to which application of the code as envisioned can be made. With slight modifications, the code system can be applied also to the polar and tropical regions.

However, of more immediate concern are the following:

a. an application and evaluation of the codification system by a group of qualified forecasters, evaluating the degree of objectivity in application and the accuracy of the code in depicting the flow characteristics of the analyzed map;

b. an increase in the degree of objectivity in coding the intensity of flow across the 10-degree zones and in coding the symmetry or asymmetry of low pressure systems when border-line conditions exist; and

c. establishment of a small unit or the designation of an existing organization, such as AROWA, to run feasibility tests on proposed uses of the code, in particular, attempt analogue selection from a three- to five-year punch-card file of coded maps, October through March, for one selected level.

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JA 22 60 9630
FE 4 60 9666

Thesis 29814
C759 Cox
A map codification system.